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Digitalization in Agriculture: Digital Revolution in Agriculture – Industry 4.0

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Abstract This paper describes the high-tech solutions presented in the use of innovative Industry 4.0 technologies such as cloud-based software, Drones, IoT, Blockchain and Big Data. Paper explains the magnitude of global problems caused by agricultural expansion and the benefits of integrating modern technologies into the agricultural system. Research and personal experience and expertise in the industry by the authors are included, along with the latest trends in agriculture. Paper will indicate the importance of ICT in modern Agriculture. Unlike the traditional approach to doing aiculture, which was based on an optimal combination of resources and a strategy of cost advantage, open IT innovation has become the main driver of agriculture growth and productivity, and innovativeness is one of the strategic factors that can help agriculture to change in the existing market limitations

Keywords: • agriculture • IoT • drone • ICT • industry 4.0 • agremo •

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1 Introduction

Information and communication technology (ICT) is the basis of digital industrial revolution that today defines how modern companies operate and the global market functions. These technologies have essentially changed the way companies operate and create a competitive position for themselves in the market and have brought numerous advantages in terms of saving energy, space, money and time. ICTs have also facilitated management and improved flexibility of business systems, and provided for more reliable and secure operations. The main question is: "What will the fourth industrial revolution change in the way companies do business"? The main effect of the Industrial revolution 4.0 is a creation of digital economy that combines the use of Internet with other advanced technologies that support companies' businesses and cause significant disruption in the business environment.

According to Schwab (2016), global businesses in Industrial revolution 4.0 will change not only the way companies operate, but also the way people live and communicate. Industrial revolution 4.0 according to Smokvina (2016), brings advanced industrial production, which relies partly on modern technologies for production automation, data processing and data exchange.

This new industrial production framework merges two areas that used to be separate – robotics and e-business. In the core of the fourth industrial revolution lies the power of three technological innovations: Automatization, Internet of Things and Artificial intelligence, Berger (2016).

Industrial, economic and business models are changing fundamentally and humans are being removed from immediate production and monitoring of manufacturing processes. In this way production can be accelerated and the number of halts and problems minimized.

According to Smokvina (2016), the fourth industrial revolution is based on six principles, which define the characteristics of the modern business environment:

1. Interoperability – the ability of companies and people to connect and communicate in a cyber-physical system;
2. Virtualization – entails creation of a virtual copy of the physical world within a cyber-physical system in order to monitor and connect the system;
3. Decentralization – moving decision-making away from a few core people in a company. Product-related decisions have been transferred to consumers, who increasingly demand individualized products;
4. Capacity to operate in real time – the data are collected and processed immediately. Production and conditions in manufacturing facilities are monitored constantly, and production is automatically shifted elsewhere in case of a disruption;
5. Service-orientation – service architecture of companies is comprehensive and takes place via interconnected web services and Internet of Things;
6. Modularity – thanks to standardized hardware and software systems, production can be flexibly adjusted to meet the manufacturer's requirements.

The five digital technologies which are presented the basic concept for digital transformation are (EC, 2014, Digital transformation of European Industry):

1. Mobility and mobile applications (Technologies that enable voice and data connections between people, and objects;
2. Social media (social networks – Facebook, LinkedIn, blogs, and other.
3. Cloud – Cloud computing is a model for enabling convenient, on-demand network access to a shared computer resources (e.g. networks, servers, storage, softvare and other;
4. Big Data Analytics – process of collecting, organizing and analyzing large sets of data ("big data") from variety of different sources to discover patterns and other information;
5. The Internet Of Things (IoT) – Describes the network of physical objects that feature an IP address for internet connectivity.

Today, in agriculture production, many farmers are already using digital technologies such as smart phones, tablets, in-field sensors, drones and satellites. These technologies provide a range of farming solutions such as remote measurement of soil conditions, better water management and livestock and crop monitoring. By analysing the data collected, farmers can gain insight into likely future crop patterns or animal health and welfare. This enables them to plan more effectively and be more efficient. Potential benefits of the use of digital technologies may include improved crop yields and animal performance, optimisation of process inputs and labour reduction, all of which increase profitability. Digitalization can also improve working conditions for farmers and reduce the environmental impacts of agriculture.

The EIP-AGRI Focus Group (2016) for Precision Farming identified a range of measures that promote the use of technologies by farmers, including the following:

1. The introduction and uptake of technologies requires new skills and knowledge for farmers and advisers. Raising awareness and organising training on a regional/local level is essential, especially to reach small and medium-sized farms, where the use of digital technologies is not always thought of as profitable.
2. The development of specific data analysis tools, with a special focus on costs-benefits, can help farm advisers to play a critical role in informing farmers on digital technologies.

Figure 1: Digital transformation in agriculture.
(Source: EIP-AGRI Brochure Operational Groups Update 2016)

Digitalization of soil should include merging various technologies which would allow us to gather more information, create historical records and intelligent forecasts based on collected data. This kind of system would bring the intelligent decision making in farming. Some of the benefits of proposed system are:

- Better quality of crops and higher yields per square meter;
- The decrease of negative environmental impact & prevention of soil erosion;
- Reduction of water & pesticide usage.

Back in 2015, more than 30 % t of all value created with agricultural machinery worldwide came from software, electronics and sensors, surpassing the value created in the automotive industry three times over. It is essential for farmers and for the environment that processes are adapted to a digital technology concept because innovative processes can potentially lead to efficient and resourcefriendly sustainable farming. Two terms crop up at regular intervals: "precision farming" and "smart farming".

“Precision farming” is the targeted management of agricultural land using smart electronics. Examples include electronic devices for sensor-assisted soil assessment, the automated monitoring of free-ranging animals on pastures and the targeted control of agricultural machinery. Modern differentiated farming methods enable the management of spatial and temporal variability within plots of land. Precision farming is an agricultural concept involving new production and management methods that make intensive use of data about a specific location and crop. Sensor technologies and application methods are used to optimise production processes and growth conditions. In contrast to conventional agricultural methods, using digital data can increase resource and cost efficiency as well as reduce environmental impact. Aerial images taken using drones provide valuable information about fields, including for example soil quality, unwanted plants and plant diseases. Data is available relatively quickly and appropriate measures can be taken.

Smart farming (also known as Farming 4.0 and digital farming) is the application of information and data technologies for optimizing complex farming systems. The integration of smart agricultural technologies and modern data technologies enables seed planting to be adapted to a specific field to ensure an efficient production process. The application of information and data technologies supports farmers in making informed decisions based on concrete data. Smart farming is also based on precise control electronics. This paves the way for enabling agricultural machines to communicate among themselves as they can all access electronic field record files.

But the main question is. “ How does a farmer process all this information?”. There are farm management systems, agricultural apps and online platforms to support farmers. "Smart farming", often also referred to as "Farming 4.0", involves not just individual machines but all farm operations. Farmers can access real-time data on mobile devices (mobile phones or tablets). Data about, for example, the condition of soil and plants, terrain, climate, weather, resource usage, manpower, funding applications is collected, processed and evaluated. An agricultural business rarely purchases modern machinery and equipment from a single manufacturer. So choosing equipment providers not only depends on how efficient the equipment is, but also whether devices can be flexibly connected with each other.

2 Digital technology in process of digital transformation

2.1 Blockchain technology

In theory, the goal would be to treat 1 square meter (sqm) of soil as a Soil Basic Unit (SBU) – congruent, square shape with sides of 1m by 1m. SBU cannot be divided into smaller units, similar to the pixel. Every SBU has 4 vertices. Each vertex is defined by geo-referenced data – point's longitude and latitude. Every SBU inherits its name from its 4 vertices, (vertex 1 lat/lon; v2 lat/lon; v3 lat/lon; v4 lat/lon;), e.g. (44.966069, 19.856436 ; 44.966070, 19.856436; 44.966069, 19.856437 ; 44.966070, 19.856437). Here we would like to introduce Blockchain, as a centerpiece of the system, as we will treat every SBU as a distributed ledger. SBU will work as a database updated independently by each node included in the network. Nodes will be data collecting platforms such as a cadastral database; drone analytics platform; IoT communication platform; farm management software, etc. Every single node on the network processes every transaction, coming to its own conclusions and then voting on those conclusions to make certain that the majority of network agrees with the conclusions. This will allow the agriculture system to manage a historical diary of records for every square meter – SBU. By doing this we are learning towards efficiency and maximizing yields of SBU. It is in line with the agricultural strategy of vertical growth. Depending on how we want to present the data, it can be stored on blockchain in one of three ways:

- Unencrypted data - can be read by every node in the network, and is fully transparent.
- Encrypted data - can be accessed only by participants with a decryption token. The token allows access to the data on the blockchain and can proove who added the data and when it was added.
- Hashed data - can be presented together with the function that created it, to show the data wasn't tampered with. Blockchain technology will create a continuously growing historical list of records – blocks, for each SBU

Every input collected by platforms (nodes) in the network is realized as a transaction and is stored in a block. That means that when a tractor's GPS or a seeder control unit, which is also an IoT device, sends some data such as variable seeding rate back to its mother platform, every seeding rate per SBU will be stored on SBU's blocks. This means that we want to create a historical record for every square meter of soil, and every action (transaction) of every agricultural operation that took place on that SBU and information extracted from it. Some of the information stored on a block could be:

- Type of a crop;
- Sowing rate;
- Yield;
- Weed pressure;
- Stresses occurring – diseases, irrigation, pest;
- Fertilizer rates;
- Applied herbicides;
- Moisture and
- Minerals.

2.2 IOT technology

Internet of things (IoT) is all devices connected to the Internet, which communicate and exchange date with each other or with cloud-based data-collecting platforms. IoT can be a sensor, vehicle, home appliance or any other piece of electronics, and is used to improve processes by collecting data, analyzing it and performing an adequate action. Communication and exchange of data through a network is crucial for IoT functionality. The IoT network consists of a device or a sensor with a communication module, communication protocol, edge device or a router and a cloud data center. In agriculture IoT devices are used as sensors on the field measuring climate conditions – moisture of ground, air humidity, temperature; detecting pests – pest traps, improving pest control and saving the yield by monitoring insect activities.

Some agricultural hardware producers, such as John Deere, are incorporating specialized IoT devices into their products. One of the examples is a piece of their planting equipment – row unit. In this example, John Deere's seeder has a sensor which communicates with a driver, by showing pressure applied to each seed as it's planted. Sensors will send the pressure information, but it will also provide data about the softness of the soil. The farmer then can adjust the pressure, in order to plant the seed on the right depth, and on the right distance. John Deere's sensors can also communicate with its mother cloud platform where all data are processed and stored. E.g. variable seeding rate for each sqm – seeding distance, and seeding depth. The same principle works with sprayers, where a device will communicate the herbicide prescriptions and spraying maps. Automatic sensor communication with cloud-based mother platforms are allowing us to automatize and improve processes – such as irrigation, spraying, seeding, harvesting etc.

Besides improving processes, this technology is making them Intelligent, as processes are based on sensor-collected data. Storing valuable information such as spraying maps, yield maps, soil moisture, seeding rates, as individual transactions on blockchain blocks for each SBU, will provide us with historical overview and conditions for intelligent decision making based on historical data.

2.3 Drone analytics

One of the main challenges for farming is large cultivated areas and inefficient crop monitoring. Until recently, the most advanced form of monitoring was satellite imagery. The main limitation of such practice was a high price, fixed interval of taking images, and cloud interference which could lower the quality and precision of the output. Drone technology solves that problems and offers a variety of crop monitoring possibilities at a lower cost. It can be utilized for any of the vegetative or reproductive growth stages in the crop life cycle. Unlike satellites, drones have a versatile function in precision agriculture operations. Besides collecting data they could be used for aerial spreading of seeds and spraying. One of the advantages of drone tech is an integration of various sensors which could be used for data collecting:

- RGB sensor;
- Multispectral & Hyperspectral sensor;
- Thermal sensor;
- Gyroscope Collected data is transferred into orthomosaic maps, which are eligible for analysis and extracting the drone analytics.

Today, digital solutions can provide valuable data and evaluate sources of stress for every sqm based on the compiled orthomosaic (Agremo, 2018). Data could show population and number of plants on the field or different types of stress that are affecting the field and the plants. As all of the drone data is georeferenced with a timestamp, storing such information on an SBU block as a new transaction is pretty straightforward. A good example of the transaction would be the measured plant density for the SBU. E.g. 10 plants/ sqm, which we could compare with the seeding map created by an IoT device.

2.4 Big Data Analytics

Accumulation of data from various sources improves the agricultural knowledge base. Storing all data in blocks will allow us to have a historical overview of all the actions performed on each SBU. Imagine what we could do if we know historical data for every square meter of agricultural land, ranging 50 years back. We could know all the crop cycles, yields, problems, stresses; each agricultural take measure, with every tool used in the process, following the weather conditions. Huge amounts of data would be a challenge to process, but by introducing AI and machine learning, historical data could get its bright future. All transactions from the past would be used for intelligent decision making, analyzing trends, the anticipation of the agricultural needs, potential threats and creating forecasts as shown in Figure 2.

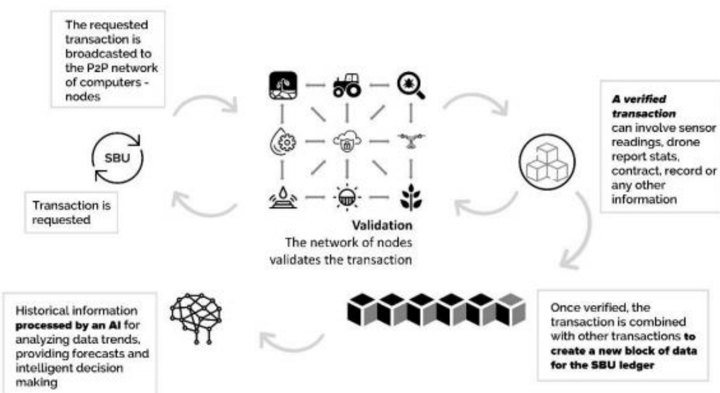

Figure 2: The inteligent agricultural decision making system.
(Source: Gibbs, 2004)

3 Agremo agribusiness platform

Agremo is a software platform for agribusinesses, crop growers and anyone interested in crop and land status and health. Agremo performs analytics from aerial imagery, leveraging computer vision and machine learning to provide "brains" for better crop management (Agremo, 2018).

Agremo platform is used in order to solve next agriculture issues:

- Solving lack of accurate and early insights into crops being grown.;
- Solving lack of accurate data based on which to plan the future. Accurate results that allow proper crop management decisions;
- Fast & proactive crop management as opposed to slow and reactive loss prevention;
- Less legwork – enormous time savings;
- Up to 65% financial savings in terms of pesticide application;
- Timely risk detection;
- Significantly higher crop performance ratio.

Figure 3: Agremo softvare platform.
(Source: Agremo. (2018))

Agremo platform could be used for monitoring, management and reporting issues:

1. PLANT COUNT MONITORING - Employing innovative technology plant counter accurately counts plants and determine stand establishment from aerial images, including different angle orientation plant rows;
2. PLANT HEALTH MONITORING - Range of analyses and reports developed to monitor plant health levels, detect stress and assess damage from different factors throughout the season. Plant health insights helps control weeds, insects and diseases, so crop threats can be identified in early stages and localized measures applied.
3. SEEDING DENSITY - In case of low quality of seeding, plants can be reseeded before it's to late, or other crucial decisions can be made timely. It also includes knowing in early stage yield to expect.
4. ANALYSIS MANAGEMENT - Simple, intuitive way to manage fields and analyses, fully equipped with tools, developed for accessing all your scans, reports and data, allowing you to monitor your fields over time.
5. FERTILIZATION PLANNING - Insights helps cut the cost by localized and precise application of fertilizer which will directly affect both yield and soil quality.
6. IRRIGATION MANAGEMENT - Water stress insights enhances water efficiency, gaining an economic advantage while also reducing environmental burdens.
7. REPORTING MANAGEMENT:
   - 7.1. STAND COUNT - Determines the number of plants in a specific area and compares it to the expected number. Stand counts are particularly suitable for seasonable crops.
   - 7.2. PLANT POPULATION - Provides information about the number of plants and is ideal for perennial plantations and orchards.
   - 7.3. PLANT STRESS ANALYSIS - Find out how healthy your crop is at key times during the growing season to intervene in a timely manner.
   - 7.4. WEED ANALYSIS - Identify weeds in time to optimize herbicide usage and prevent crop damage.
   - 7.5. FLOWERING ESTIMATOR - Assess flowering levels to determine the exact growth stage of your plants, choose a proper harvesting date and other.

7.6. PLANT DISEASE ANALYSIS - Analyze crops at all growth stages to obtain valuable insights into your plant's current condition.

7.7. WATER STRESS ANALYSIS - Spot areas with potential water stress and standing water to adjust your irrigation system before it affects your crop's health.

7.8. PEST ANALYSIS - Pinpoint infested areas and apply pesticide only where and if needed.

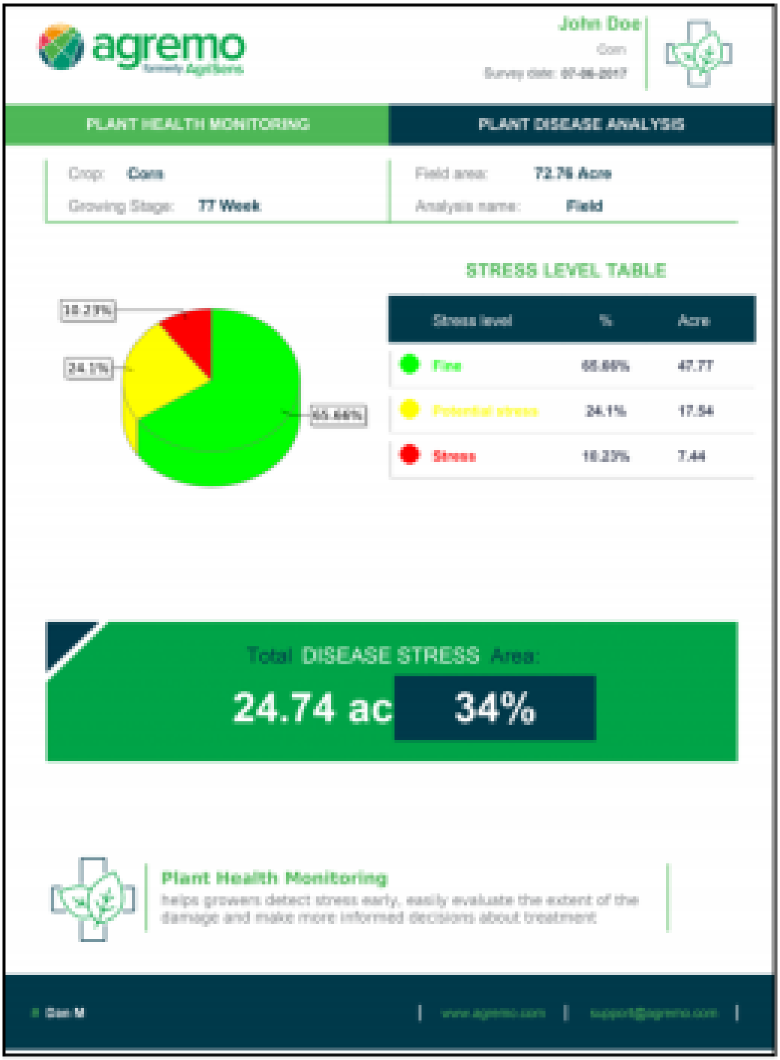

Figure 4: Plant disease analysis

The basics steps in Agremo process are: collect the data, generate maps, analyze images, and manage fields (see Figure 5.)

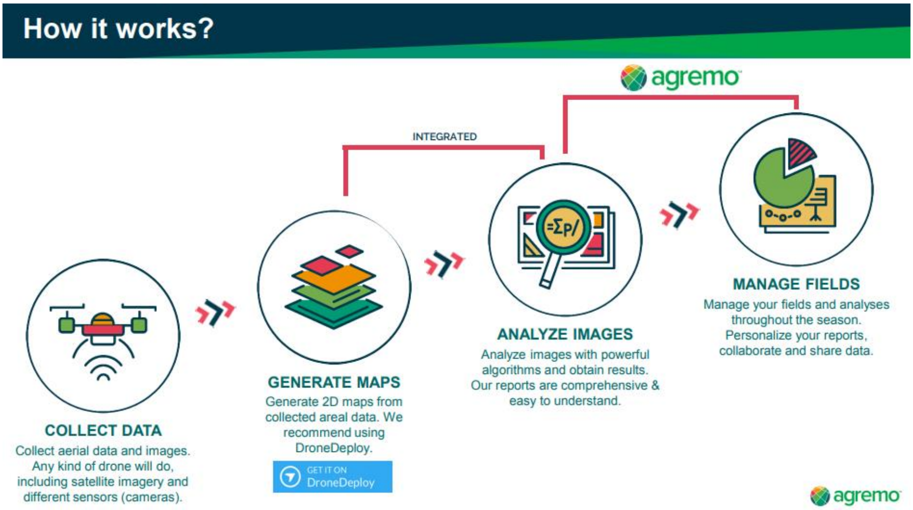

Figure 5: Agremo implementation steps

The main values created by Agremo Tool for better crop management are:

- Maximize profit by maximizing crop performance ratio;
- Reduce the costs of production by localized measures;
- Optimize your crop monitoring processes and save time;
- React proactively to stress problems and reduce risks Increase productivity throughout the season;
- Remove uncertainty in the results of your production;
- Platform to digitalize agriculture;
- Obtain data, data, and more data …;
- Use it as the marketing and sales channel;
- Collaborate and exchange data and outputs with others;
- Make effective strategic decisions based on facts.

6 Conclusion

Innovation is essential for a competitive and sustainable European farming and forestry sector. Today, many farmers are already using digital technologies such as smart phones, tablets, in-field sensors, drones and satellites. These technologies provide a range of farming solutions such as remote measurement of soil conditions, better water management and livestock and crop monitoring. By analysing the data collected, farmers can gain insight into likely future crop patterns or animal health and welfare. This enables them to plan more effectively and be more efficient. Potential benefits of the use of digital technologies may include improved crop yields and animal performance, optimisation of process inputs and labour reduction, all of which increase profitability. Digitisation can also improve working conditions for farmers and reduce the environmental impacts of agriculture. Another gain relates to agricultural data flows. Improving information flows up and downstream in agri-food chains could result in a wide range of benefits for those involved, including farmers and stakeholders in distribution and retail.

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